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THE SHIP CHARACTERISTICS AND IMPROVEMENT BOARD: A CRITICAL REVIEW

by

Kevin Michael Sweeney

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Thesis Advisor: Paul M. Carrick

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One of the fundamental objectives of the ship design process in the U.S. Navy is the determination of the characteristics of a new ship. These characteristics are based on operational requirements, technical feasibility and cost constraints. This thesis is a critical review of the OPNAV organization responsible for this process: the Ship Characteristics and Improvement Board (SCIB). This thesis reviews the evolution of the ship design process, defines the mission and functions of the SCIB, and outlines SCIB procedures and policies. This thesis also focuses on the cost estimating methodologies NAVSEA and the Naval Center for Cost Analysis (NCA) use to derive and validate ship program costs. The results of this thesis indicate the need to improve the SCIB process through changes in the SCIB working groups. The Navy also needs to develop an automated

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The Ship Characteristics and Improvement Board:
A Critical Review

by

Kevin Michael Sweeney
Lieutenant, United States Navy
B.S., United States Naval Academy, 1982

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Author: Kevin M. Sweeney
Kevin M. Sweeney

Approved by: Paul M Carrick
Paul M. Carrick, Thesis Advisor

Richard Elster, Second Reader

David R. Whipple, Chairman
Department of Administrative Scie.

K. T. Marshall
Kneale T. Marshall,
Dean of Information and Policy Sciences

ABSTRACT

One of the fundamental objectives of the ship design process in the U.S. Navy is the determination of the characteristics of a new ship. These characteristics are based on operational requirements, technical feasibility and cost constraints. This thesis is a critical review of the OPNAV organization responsible for this process: the Ship Characteristic and Improvement Board (SCIB). This thesis reviews the evolution of the ship design process, defines the mission and functions of the SCIB, and outlines SCIB procedures and policies. This thesis also focuses on the cost estimating methodologies NAVSEA and the Naval Center for Cost Analysis (NCA) use to derive and validate ship program costs. The results of this thesis indicate the need to improve the SCIB process through changes in the SCIB working groups. The Navy also needs to develop an automated data base for ship costs to improve the quality of cost estimating.

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I. INTRODUCTION

A. FOCUS OF THE STUDY

One of the fundamental objectives of the ship design process in the U.S. Navy is the determination of the characteristics of a new ship based on operational requirements, technical feasibility, size and cost constraints. The key to the success of the design process is communication between those responsible for planning the Naval warfare force structure in the Office of the Chief of Naval Operations (OPNAV) and the ship design engineers at the Naval Sea Systems Command (NAVSEA). This process has slowly evolved over the past 100 years.

One of the most significant recent improvements in the ship design process and its communication links was the establishment of the Ship Characteristics and Improvement Board (SCIB). The SCIB's primary mission is to assist the Chief of Naval Operations (CNO) in meeting his responsibilities pertaining to ship acquisition and conversion programs. The establishment of the SCIB has temporarily ended the debate between OPNAV and NAVSEA on how ship characteristics should be developed and approved for both ship acquisition and fleet modernization programs. [Ref. 1:p. 39] Finally, ship characteristics are defined as:

> ...a list of ship properties and requirements. These include: physical properties like displacement and

length; payload items like guns, ammunition and radars; and performance requirements like endurance, speed and "best practicable seaworthiness." These are used by the Chief of Naval Operations as the specifications of what is wanted: "single sheet characteristics" initiated Feasibility Studies, "proposal characteristics" initiated Preliminary Design, and "approved characteristics" resulting from Preliminary Design. [Ref. 2:p. 88]

B. OBJECTIVES

This thesis will review SCIB policies and procedures, evaluate the performance of the SCIB organization on the ship design and acquisition process. More specifically, this thesis will focus upon the procedures OPNAV and the Naval Center for Cost Analysis (NCA) use to derive and validate program costs.

C. RESEARCH QUESTIONS

In order to accomplish the above objectives, the primary research questions addressed in this paper are: what is the SCIB and how does it function? The following ancillary research questions are used to aid in determining the answers to the above questions:

1. Why was the SCIB established (historical perspective)?
2. How has the SCIB affected changes in the characteristics decision making process for naval ships?
3. What measures of effectiveness have been established for the SCIB?
4. How are program costs presented by NAVSEA validated?
5. Are cost estimates derived in a timely manner and at such a level of disaggregation as to affect tradeoffs in the design process?

6. How well has the SCIB performed and where can improvements to the process be made?

D. RESEARCH METHODOLOGY

This research was conducted by intensely reviewing instructions, memorandums, publications, and reports originated inside and outside of the Navy. Personal interviews were conducted with the SCIB staff, OPNAV personnel and analysts at NCA.

E. SCOPE OF THE STUDY

This study is a critical review of the SCIB design process. It is an analysis of how the OPNAV organization has changed the ship characteristics decision process through the SCIB. It is not a review of the NAVSEA organization and its detailed procedures for ship design and cost estimation.

F. LIMITATIONS

Critical documentation on the SCIB and NCA is very limited due to the recent establishment of both organizations (1982 and 1985, respectively). Therefore, a major part of this thesis is based on written instructions, personal interviews and the author's experience as a member of SCIB working groups for 16 months

G. ASSUMPTIONS

It is assumed throughout this thesis that the reader is familiar with basic terminology and OPNAV's organization and functions.

H. ORGANIZATION

This thesis is divided into six chapters. Chapter I is the introduction. Chapter II discusses the SCIB organization, mission and function. Chapter III reviews the history of the ship characteristics decision process and why the SCIB was established. Chapter IV outlines the SCIB process for new acquisitions and ship modernization programs. Chapter V reviews OPNAV cost validation procedures and the role of NCA. Chapter VI presents a summary, emerging problems and recommendations.

II. THE SHIP CHARACTERISTICS AND IMPROVEMENT BOARD

A. MISSION AND FUNCTIONS

The CNO Executive Board (CEB) provides the CNO advice on "strategy, policy, force composition, operational requirements, organization, personnel or other issues requiring a CNO decision." [Ref. 3:p. 1] In September 1982, the SCIB was added as a special panel to the CEB. OPNAV Instruction 5420.2P (14 April 1988) outlines the charter for the CEB and its special panels. Figure 1 details the CEB organization.

The mission of the SCIB is to:

> ...assist the Chief of Naval Operations in meeting those responsibilities pertaining to ship acquisition and improvement by coordinating the formulation of Navy shipbuilding and conversion programs. Staff all aspects of ship acquisition and improvement in order to provide recommendations to the Chief of Naval Operations. SCIB tasks include the centralized formulation and coordination of the Navy's shipbuilding and conversion programs, the Fleet Modernization Program (FMP) and ship's characteristics determination for the active and reserve fleets. The SCIB is responsible for coordination of the planning, programming, budgeting, and support necessary for the efficient and cost effective execution of these responsibilities. [Ref. 3]

The activities of the SCIB are divided into seven key functions:

1. Advise the CNO on all matters related to ship acquisition and improvement (new construction, conversion, characteristics and alterations).

2. Coordinate, with ship and program sponsors, all ship acquisition programs (program planning, characteristics development, procurement strategy, Integrated Logistics Support and Training plans).

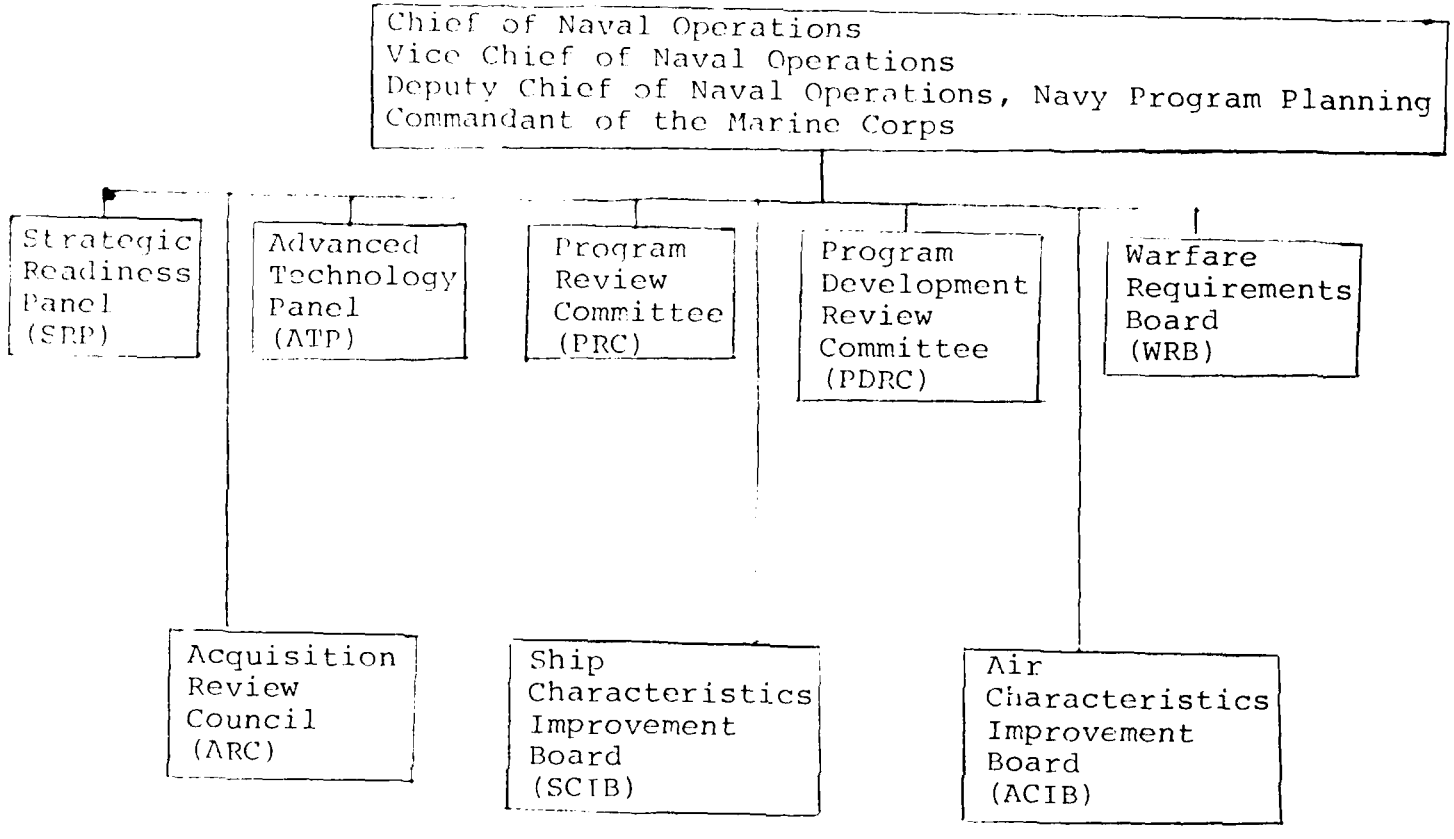


Figure 1. CNO Executive Board (CEB)

3. Affect necessary liaison for ship acquisition and improvement programs with all interested activities within and outside of the Navy including the Office of the Secretary of Defense (OSD), Office of Management and Budget (OMB) and Congress.

4. Monitor the Fleet Modernization Program (FMP) through the permanent FMP Working Group.

5. Approve or disapprove FMP Working Group proposals to change military characteristics of a ship.

6. With respect to ship requirements/characteristics development:

   a. Develop and promulgate initial ship requirements guidance in response to an approved Tentative Operational Requirement (TOR);

   b. Approve all subsequent requirements/characteristics modifications;

   c. Review and approve all ships-related Program Management Proposals (PMPs).

7. Review all new construction programs at least once during construction. [Ref. 3]

B. MEMBERSHIP

The chairman of the SCIB is the Assistant Chief of Naval Operations for Surface Warfare (OP-03). The board consists of both permanent and adjunct members. A permanent staff has been established to assist the SCIB's executive secretary (OP-03C) in the coordination of all SCIB activities. This staff includes two civilian billets from NAVSEA to "ensure continuity, corporate memory and consistency in the technical information presented to the board." [Ref. 1:p. 41] Figure 2 presents the full SCIB membership.

Permanent Members:

Assistant Chief of Naval Operations,
Surface Warfare (OP-03)--Chairman
Assistant Chief of Naval Operations
Undersea Warfare (OP-02)
Assistant Chief of Naval Operations
Air Warfare (OP-05)
Deputy Chief of Naval Operations
Logistics (OP-04)
Deputy Chief of Naval Operations
Naval Warfare (OP-07)
Deputy Chief of Naval Operations
Navy Program Planning (OP-08)
Commander, Naval Sea Systems Command
Commander, Space and Naval Warfare Command

Adjunct Members:

Deputy Chief of Naval Operations
Manpower, Personnel and Training (OP-01)
Deputy Chief of Naval Operations
Plans, Policy and Operations (OP-06)
Director, Space Command and Control (OP-094)
Director, Research and Development Requirements,
Test and Evaluation (OP-098)
Director, Naval Center for Cost Analysis
President, Board of Inspection and Survey
Commandant of the Marine Corps (Research and
Development)
Assistant Secretary of the Navy (Shipbuilding and
Logistics)
Assistant Secretary of the Navy (Research, Engineering
and Systems)

Figure 2. SCIB Membership

C. WORKING GROUPS

"To ensure the free flow of information," OPNAV Instruction 5420.2P calls for the establishment of a SCIB working group for each new ship acquisition program or any other issue under review by the SCIB. The division director (flag officer) within OPNAV sponsoring the program is normally designated the working group director. The group is made up of representatives from each of the SCIB principals. Simply put, the OPNAV representatives define operational requirements and the NAVSEA representatives present the technical solutions to these requirements. The goal of the working group is to resolve issues at the lowest level possible before making recommendations to the full SCIB. Figure 3 shows a typical SCIB working group.

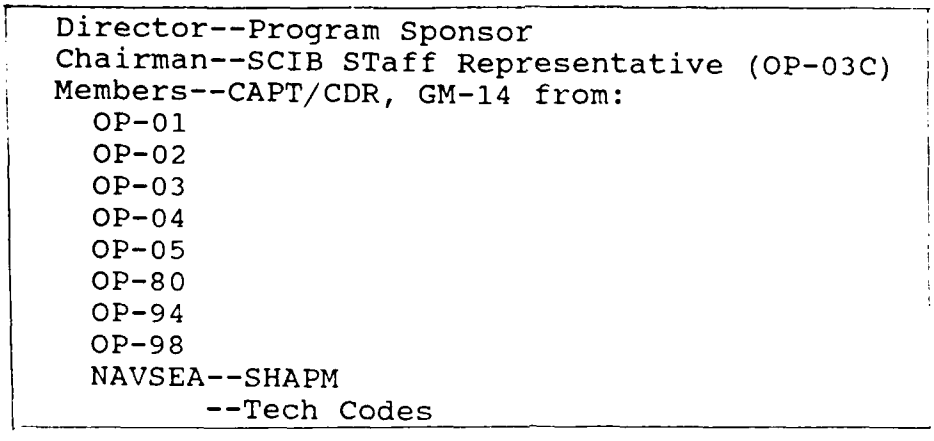


Figure 3. SCIB Working Group

D. SUB-PANELS

The SCIB has two sub-panels. The Surface Ship Survivability Group (SSSG) was established to develop and promulgate policies, plans and programs to ensure ships maintain the highest state of operational readiness and warfighting sustainability. These are achieved through improved (1) surface ship survivability, (2) submarine survivability, (3) chemical, biological, and radiological defense, and (4) arctic-cold weather preparations.

The Fleet Modernization Working Group (FMP) develops proposed changes to the military characteristics of existing ships. This is accomplished through the development of individual Warfighting Improvement Plans (WIPs) for each ship class. Through the WIP process the SCIB is able to control ship characteristics after fleet introduction.

E. CURRENT PROGRAMS

Figure 4 provides a brief listing of some of the major programs under review by the SCIB as of April 1988. [Ref. 4]

AR(x)	New Battle Damage Repair Ship
ASR(x)	New Sub Rescue Ship
AS(x)	New Sub Tender
ATR(x)	New Towing and Rescue Ship
DDG 51	Characteristics Development for Flight III
L(x)	New Amphibious Ship
LHD 5	Block Upgrade and Propulsion Alternative
PBC	New Coastal Patrol Boat
T-AGS(0)	New Ocean Research and Survey Ship

Figure 4. Current SCIB Programs

F. SUMMARY

In summary, the SCIB is a three star level decision group established in 1982 to advise the CNO on new ship acquisition and conversion programs. It is designed to enhance the dialogue and exchange of information between those responsible for planning the Naval warfare force structure in OPNAV and the design engineers at NAVSEA. Programs are reviewed and most issues are resolved at the working group level before recommendations are forwarded for full SCIB approval. Before outlining SCIB policies and procedures, the thesis will review the factors that influenced the establishment of the SCIB.

III. EVOLUTION OF THE SHIP DESIGN PROCESS

One word best describes the Navy's ship design process: change.

> Over the last 50 years the U.S. Navy has had a constantly evolving ship design process. It has been influenced by technology, politics, the expediencies of war, management theories, and the needs of the Fleet. [Ref. 2:p. 88]

From 1900 through World War II, the Navy's General Board identified operational requirements and established ships' characteristics. The General Board consisted of "distinguished flag officers of the line who were within a few years of retirement." [Ref. 2:p. 91] In 1945 the Secretary of the Navy replaced the General Board with the Ships Characteristics Board (SCB). The SCB voting members were again senior line officers representing the principal OPNAV offices and material bureaus. Most of the work in the development of ship characteristics was done in a series of working level meetings. Preliminary characteristics were developed during the feasibility study phase. The Bureau of Ships provided cost and feasibility studies for the options under consideration. Once the working group reached a consensus on the key issues and the resulting characteristics were sound, they would be presented to the SCB for approval. The preliminary design phase would commence after board approval of the preliminary characteristics. During this phase engineering solutions were developed for the

various options identified in the feasibility phase. At the end of the preliminary design phase, the SCB would meet again to select an option and approve the final version of the characteristics. The redefined Approved Characteristics would allow contract design to commence. Subsequent characteristics changes would be through the SCB-approved modifications. [Ref. 1:pp. 41-42]

Over the years new management layers were added to both OPNAV and the Naval Ships Systems Command (successor to the Bureau of Ships). "And while there were some notable exceptions, dialogue became less direct, and also less efficient." [Ref. 5:p. 41] By the mid-1960s the SCB fell into disuse and was eventually replaced by the Ship Acquisition and Improvement Council (SAIC) and then the Ship Acquisition and Improvement Panel (SAIP).

In 1974 the Naval Ship Systems Command and the Naval Ordnance Systems Command merged to form the Naval Sea Systems Command (NAVSEA). In 1979 the Naval Ship Engineering Center was merged into NAVSEA Headquarters. The resulting organization brought ship system engineering and design, ship material, hull, machinery and combat system all under one command. However, the Commander of NAVSEA was not a voting member of the SAIC or SAIP.

In a letter dated 9 February 1982, an ostensibly frustrated Vice Commander of NAVSEA stated:

> The purpose of this letter is to recommend improvements to the process now in use within the Navy for determining the

characteristics of our new ships. The exchange of information between the Office of the Chief of Naval Operations and the Naval Sea Systems Command regarding military requirements, technical feasibility, characteristics, ships size, and cost is being carried out in briefings, telephone calls, and ad hoc meetings. The Top Level Requirements and Top Level Specifications, intended to be the mechanism formalizing the dialogue between CNO and NAVSEA, are too voluminous and cumbersome. This letter proposes a simplified process, but one that is formal and encourages early documentation of information exchanged and decision making. [Ref. 1:p. 39]

In September 1982, Admiral W.N. Small, the Vice CNO, signed a memorandum replacing the SAIP with the SCIB. Figure 5 illustrates how the chain of command between OPNAV and the

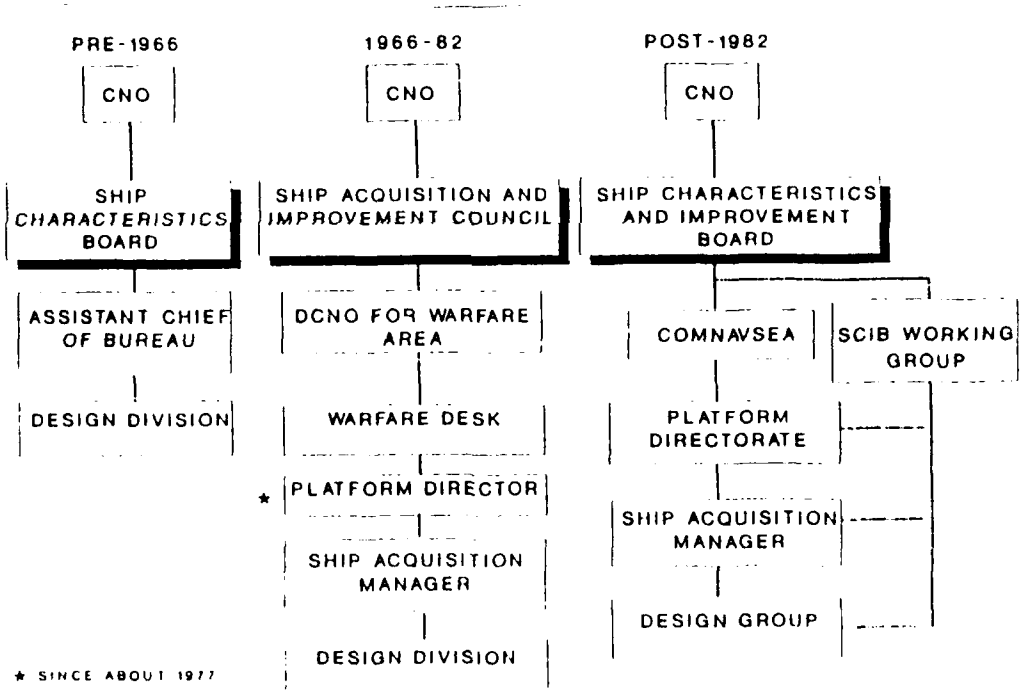


Figure 5. Ship Characteristics Chain of Command

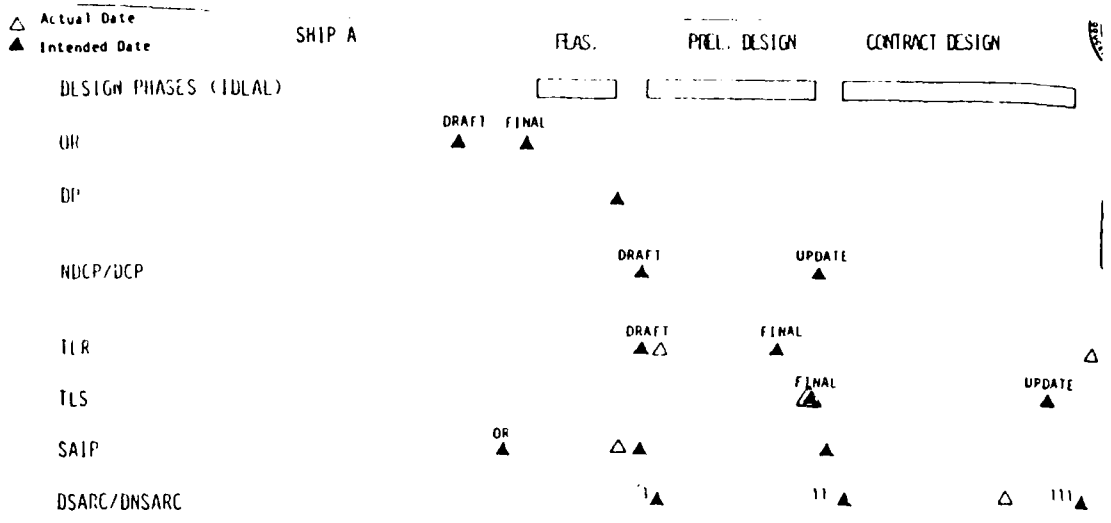
ship designers has changed through the years. The new SCIB is essentially a blending of the memberships of earlier boards and councils with a few notable exceptions. The Commander of NAVSEA and the principal Deputy and Assistant Chiefs of Naval Operations are full voting members. Also, the Office of the Secretary of the Navy is represented by two adjunct members.

In addition to the need for a direct communication link between OPNAV and NAVSEA, there were two other factors that influenced the establishment of the SCIB. The limited membership of the SAIP and the lack of a dedicated staff created an environment within OPNAV where a program sponsor could circumvent formal reviews under existing acquisition procedures until his program was well entrenched in the budget process. "Without a strong board like the SCIB, each program was developed independently causing confusion and program turbulence." [Ref. 1:p. 44]

Figures 6 and 7 show two ship acquisition histories and the type of review and documentation required by acquisition policies in effect during the late 1970s. The large number of missing documents indicates little or no program review.

> This lack of approval and consensus was characterized by rapid changes in requirements, restarts of whole design phases, and a large sense of frustration in OPNAV and NAVSEA, plus a large expenditure of scarce R&D funds for non-productive work. [Ref. 1:p. 44]

The final factor that spurred the establishment of the SCIB was the expanding shipbuilding program initiated by the



DCP	Decision Coordination Paper
DP	Developmental Proposal
DNSARC	Department of the Navy Ship Acquisition Review Council
DSARC	Defense Systems Acquisition Review Council
NACP	Navy Decision Coordination Paper
OR	Operational Requirement
SAIP	Ship Acquisition and Improvement Panel
TLR/S	Top Level Requirement/Specification

Figure 6. Schedule of Events, Milestones and Key Documents for Ship "A"

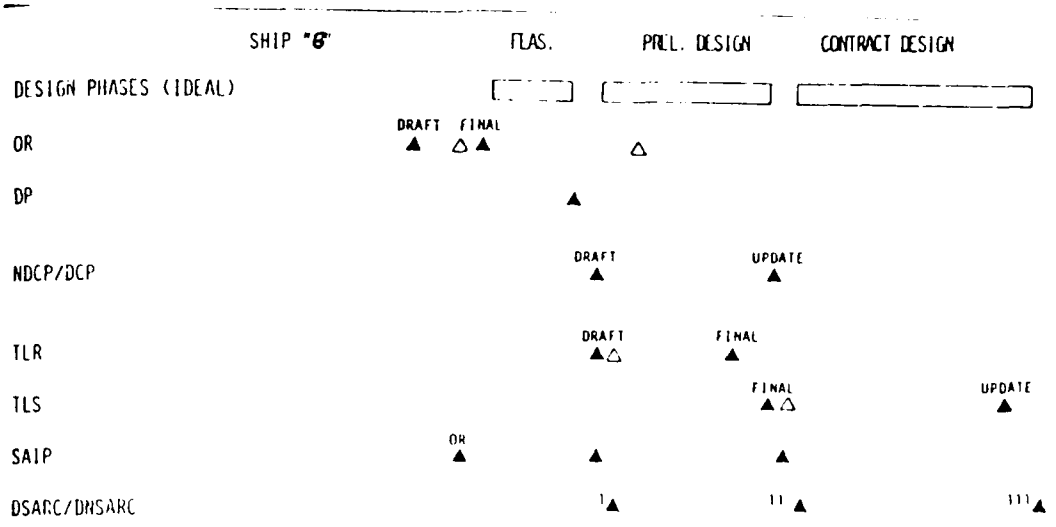


Figure 7. Schedule of Events, Milestones and Key Documents for Ship "B"

Reagan Administration. The SCIB helped the Navy articulate a clearly defined, coherent ship acquisition program when dealing with OSD and Congress. [Ref. 1:p. 44]

Chapter IV will outline the policies and procedures of the newly established SCIB.

IV. SCIB POLICIES AND PROCEDURES

A. INTRODUCTION

The major functions of the SCIB identified in Chapter II are essentially performed as elements of two broadly defined processes. The first is the process that develops the characteristics for new ships during the feasibility study, preliminary design and contract design phases. This coincides with the normal acquisition procedures defined by the program's acquisition category (ACAT). However, it should be noted that the SCIB is not the final authority for a ship's program approval. The decision forum for program approval at Milestones I, II and III is the Defense Acquisition Board (DAB) for ACAT I programs and the Navy Program Decision Meeting (NPDM) for all other programs. The second SCIB process encompasses the planning and approval of changes to characteristics for ships in the Fleet Modernization Program. This is accomplished through the Warfighting Improvement Plan (WIP) developed for each ship class. Policy and procedures for the development of naval ship characteristics are outlined in OPNAV Instruction 9010.300A (11 January 1985) and guidelines for WIP development are contained in OPNAV Instruction 9010.335 (24 February 1987). The remainder of this chapter is an outline of these policies and procedures.

B. NAVAL SHIP CHARACTERISTICS DEVELOPMENT

The first step in the acquisition process for a new ship is program initiation during the feasibility study phase. Figure 8 contains an overview of the acquisition process. This phase starts with the development and approval by OPNAV of the Tentative Operational Requirement (TOR). The TOR is originated by the program sponsor (normally OP-03), reviewed by the SCIB membership as well as the Fleet commanders, and approved by the Director of Naval Warfare (OP-07). The TOR provides the ships' design engineers at NAVSEA a general statement of the perceived requirements and desired capabilities for the new ship so alternate solutions can be identified. Figure 9 provides an outline for the TOR. NAVSEA will respond to the TOR with a Development Options Paper (DOP). At the same time the draft TOR is issued for review, a SCIB working group is formed for the new ship program. The chairman of the working group will normally be the OPNAV program sponsor. The working group will meet regularly to review the progress of the options development and provide additional guidance and tasking as necessary. Most importantly, the working group is tasked to:

> ...identify those aspects of performance early on that are major cost drivers and address the requirements for those aspects of performance initially before addressing secondary requirements. [Ref. 6:p. 2]

Once all the major requirement issues have been adequately addressed, the full SCIB meets for a briefing. All viable options, with their preliminary characteristics,

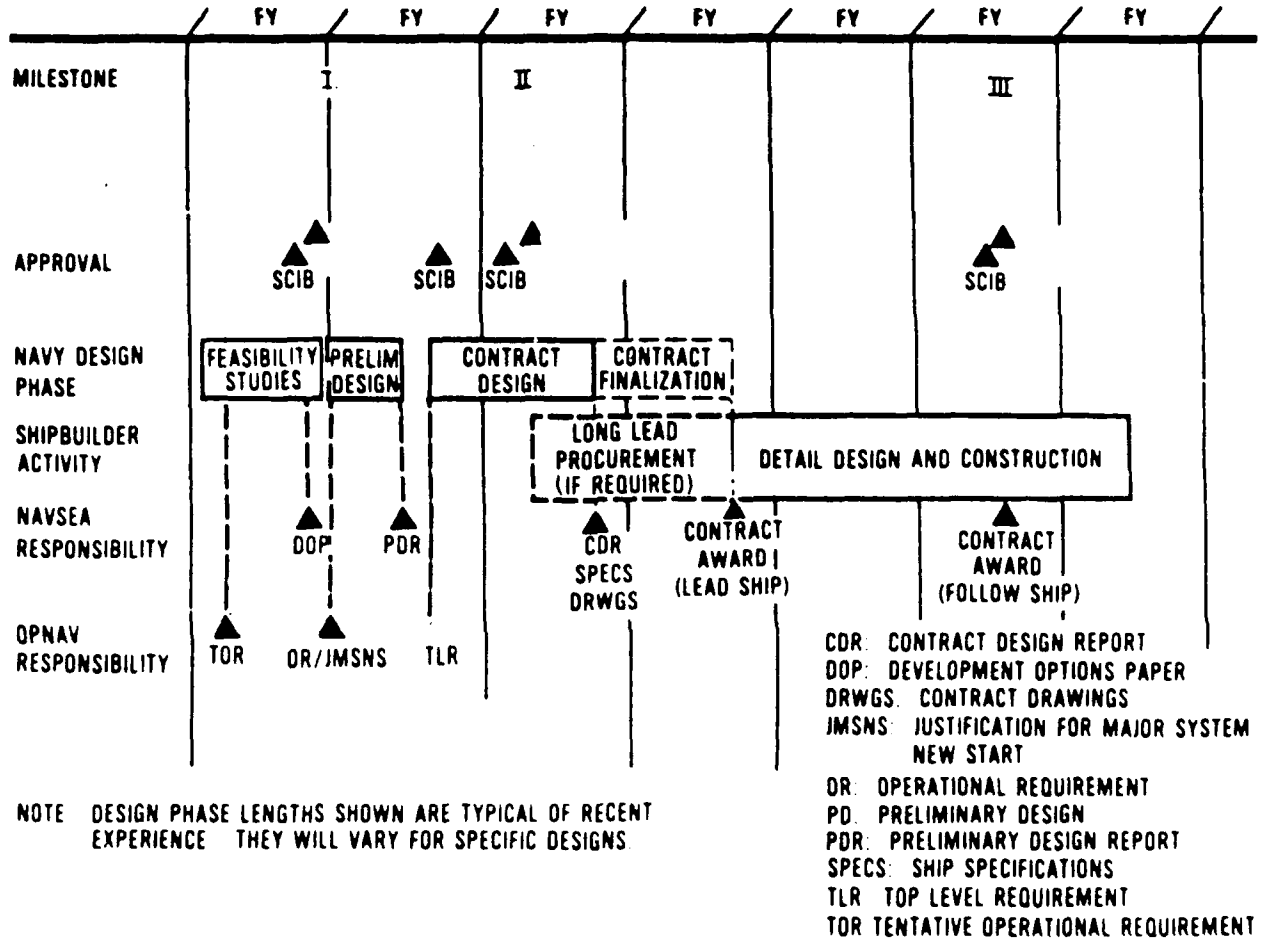


Figure 8. Overview of Naval Ship Acquisition Process

1. General Description of Operational Requirement
2. Threat
3. Shortcomings of Existing System
4. Range of Capabilities Desired
5. General Affordability Limits
6. Quantities
7. Integrated Logistics Support
8. Related Efforts

Figure 9. Format for Tentative Operational Requirement (TOR)

are provided to the SCIB in the DOP. This list of options ranges from the low cost minimum capability to the high cost maximum capability. Figure 10 provides an outline for the DOP. NAVSEA provides life cycle and Class "F" cost estimates for each alternative. These Class "F" costs are ballpark estimates "prepared in absence of minimum design and cost information based on gross parameters." [Ref. 7:p. 4] The SCIB will then select the option which best matches the desired capabilities.

1. Summary of Alternatives
2. Description of Alternatives
3. Advantages/Disadvantages of Alternatives
4. Cost-Capability Curves

Figure 10. Format for Development Options Paper (DOP)

The requirements for the selected option and its preliminary characteristics are documented in the

Operational Requirement (OR) for ACAT II and III programs. The OR has the same format and goes through the same approval process as the TOR. For an ACAT I program, a Justification for Major System New Start (JMSNS) is prepared by OPNAV instead of the OR and is approved at the OSD level. After the final approval of the OR/JMSNS is made, a Milestone I decision is made by the DAB/NPDM which initiates the preliminary design phase for the new ship.

During the preliminary design phase, the TOP Level Requirements (TLR) is developed by the program sponsor with guidance provided by the SCIB Working Group. The TLR is the Navy's primary statement of design requirements for the new ship. It expands on the OR/JMSNS and ultimately includes all the major characteristics of the new ship. [Ref. 8:p. 51] Figure 11 contains an outline for the TLR. NAVSEA will respond formally with the Preliminary Design Report (PDR) at the completion of the preliminary design phase. The PDR describes the characteristics of the specific ship design which matches the requirements stated in the TLR. The PDR also includes an updated ship acquisition cost estimate. This official Class "C" estimate is based on detailed engineering analyses of the new ship design. This estimate is also used by the program sponsor for budget submissions. [Ref. 7:p. 4] The TLR is approved by the SCIB and initiates the contract design phase (a non-milestone decision).

1. Overview

    1.1 Objectives and Scope
    1.2 Constraints
    1.3 Design Guidance
    1.4 Summary of Major Ship Characteristics

2. Mission Statement

    2.1 Mission
    2.2 Primary Tasks
    2.3 Secondary Tasks

3. Total Ship Requirements and Characteristics

    3.1 Warfare Area Capabilities
    3.2 Detectability
    3.3 Survivability, Including Passive Protection
    3.4 Mobility
    3.5 Operating Environment
    3.6 Utilization and Operational Availability
    3.7 Logistic Support
    3.8 Manning
    3.9 Flexibility for Change, Including Space and Weight Reservations
    3.10 Training

4. Subsystem Requirements and Characteristics

    4.1 Structure
    4.2 Propulsion System
    4.3 Electric Plant
    4.4 Command and Surveillance
    4.5 Auxiliary Systems
    4.6 Outfit and Furnishings
    4.7 Armament
    4.8 Other

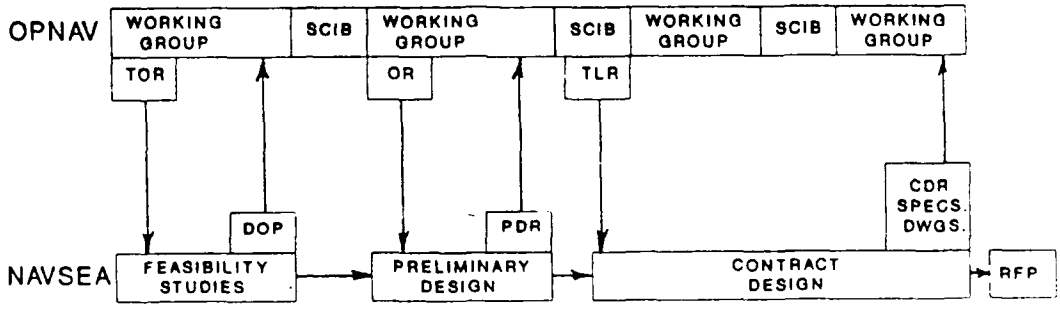
Figure 11. Format for TOP Level Requirements (TLR)

During the contract design phase the SCIB working group will be convened only to address new issues which may arise. If modifications to the TLR are necessary, the working group will recommend changes to the SCIB for approval prior to being issued by the program sponsor for incorporation into the ship design. Prior to the Milestone II decision for the program, a SCIB review meeting will be held for the new ship. For ACAT I and IIS programs, the results of this review and recommendations will be contained in a SCIB Review Memorandum (SRM). For ACAT IIC and III programs, the SCIB review will yield a Navy Decision Coordination Paper (NDCP). The DAB/NPDM will make the Milestone II decision based on these reviews. The go-ahead decision provides approval for the lead ship of the new class. At the completion of the Contract design phase, NAVSEA will issue a Contract Design Report (CDR), an update to the PDR, which summarizes how the ship design meets the requirements and constraints of the TLR.

With the lead ship approved, the program then enters the detail design and construction phase. Again any recommended changes to the TLR will be presented to the Chairman of the SCIB. He will decide whether these changes warrant a full SCIB review or can be approved by the program sponsor. The Milestone III decision serves as approval for construction of the follow-on ships. The SCIB will formally review the status of the lead ship and any changes to the TLR for the

follow-on ships (i.e., new flights for some ship class) and make recommendations to the DAB/NPDM. [Ref. 6:p. 3]

This process for the development of naval ship characteristics is very formal and highly structured. The key to the success of this process is its main coordinating element: the SCIB working group. The working group is the forum in which the ship operators and design engineers debate, resolve issues and ultimately articulate the ship requirements and characteristics. Figure 12 shows how the SCIB process has enhanced this critical dialogue. [Ref. 6:p. 45]



TOR - TENTATIVE OPERATIONAL REQUIREMENTS
DOP - DEVELOPMENT OPTIONS PAPER
OR - OPERATIONAL REQUIREMENTS
PDR - PRELIMINARY DESIGN REPORT
TLR - TOP LEVEL REQUIREMENTS
CDR - CONTRACT DESIGN REPORT
RFP - REQUEST FOR PROPOSAL

Figure 12. Operator/Designer Dialogue

C. WARFIGHTING IMPROVEMENT PLAN (WIP) DEVELOPMENT

The purpose of the WIP is "to provide procedures for the orderly planning and approval of changes to the characteristics for ships in the Fleet Modernization Program (FMP)." [Ref. 9:p. 1] The WIP identifies alterations that correct the warfighting deficiencies of the ship class, assembles these into Alteration Packages (APs) to be installed at the same time, and finally schedules their accomplishment during a ship's scheduled availability periods (i.e., Ship Restricted Availability (SRA), Phased Maintenance Availability (PMA), Regular Overhaul (ROH)).

There are three categories of ship configurations described in the WIP:

1. Baseline Configuration--This is the official description of the ship class based on the TOP Level Requirements (TLR) plus any alteration approved by the SCIB and programmed for installation during the baseline year.

2. WIP Configuration--This is the planned configuration after the next major upgrade for the ship. It represents the program sponsor's best attempt within technical and fiscal constraints to correct the ship and combat system deficiencies in the priority warfare areas. This configuration is referred to as Baseline 1.

3. Future Configuration--This configuration is a list of proposed upgrades and capabilities which have been identified as necessary to correct warfighting deficiencies. This list contains items not currently in the WIP due to cost or technical constraints and as a result from platform deficiencies for which no equipment or system has been developed yet. This configuration is referred to as Baseline 2.

The CNO's goal is to have an approved WIP for each ship class in the FMP. The program sponsor for each class

initiates the WIP development (see Figure 13) by providing the Director of Naval Warfare (OP-07) the Baseline Configuration for the ship class along with a threat assessment developed by the Director of Naval Intelligence (OP-092). OP-07 reviews this information, sets the ship warfighting priorities by mission area (ASW, AAW), and lists the warfighting deficiencies of the class against projected future threats. NAVSEA is then tasked to developed the configuration options required to correct these deficiencies. NAVSEA also performs the system engineering to assemble the individual alterations into APs. With the assistance of the permanent FMP Working Group, a SCIB briefing package is put together that contains WIP configuration options that are consistent with the prioritized warfighting deficiencies and fiscal limitations. A SCIB meeting is convened and the program sponsor presents his recommendations. If the SCIB concurs with the recommendations, an approval letter is signed by the CNO. The program sponsor and NAVSEA must then submit a signed Program Management Plan (PMP), via the Director of Navy Program Information Center (OP-80), for CNO approval and submittal for SECNAV approval.

WIPs will be reviewed annually by the program sponsor and any changes that affect ship characteristics will be presented for SCIB approval. [Ref. 9:p. 3]

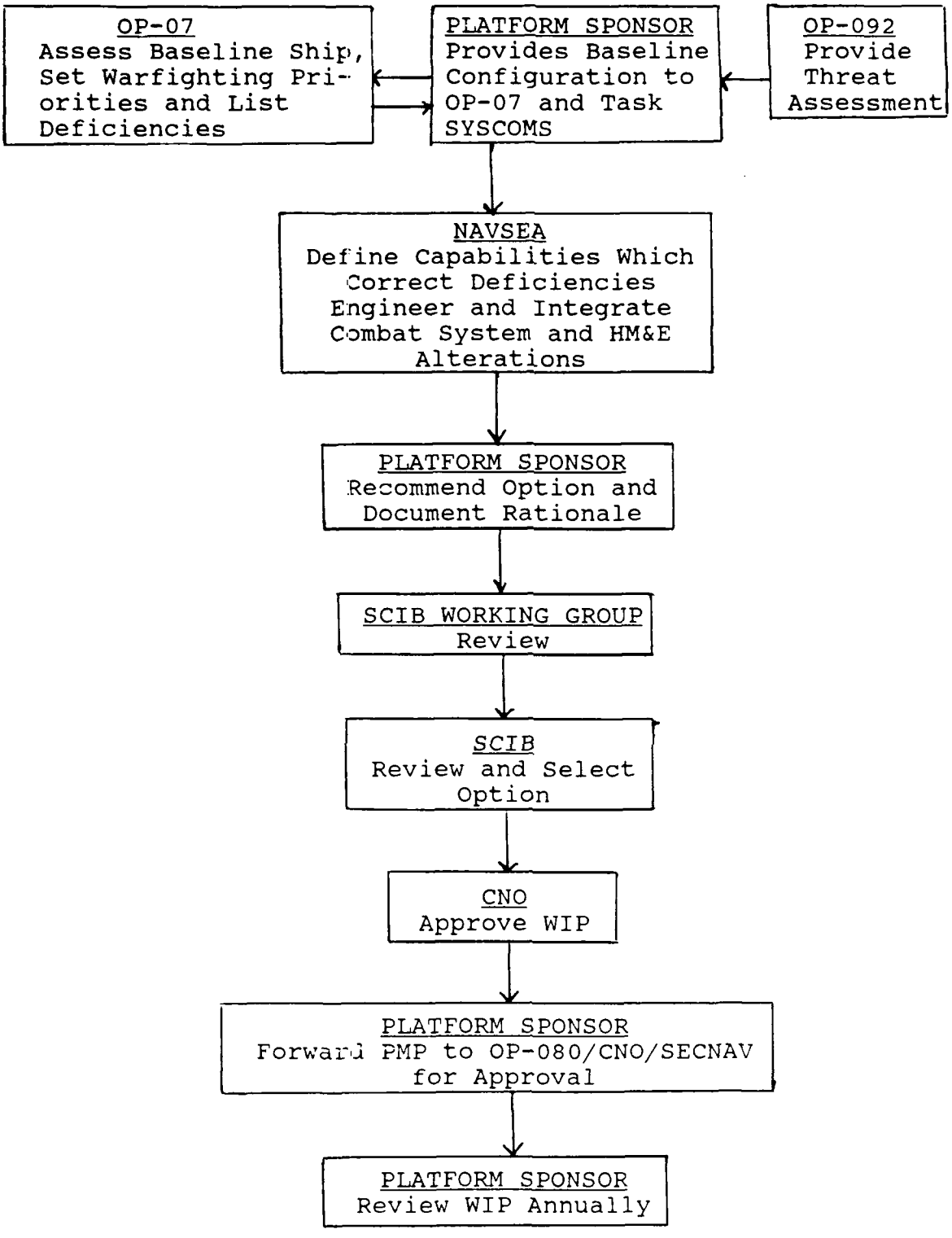


Figure 13. WIP Development and Approval

D. SUMMARY

The SCIB is responsible for the development of and changes to the characteristics of Navy ships. It does this through two processes. The first process is the development of characteristics for new ships during the early stages of the acquisition process. The approved ship characteristics are documented in the Top Level Requirements (TLR). After fleet introduction, the SCIB controls the changes in the characteristics of ships in the Fleet Modernization Program (FMP) through the Warfighting Improvement Program (WIP). The WIP process identifies warfighting deficiencies and provides the alterations required to correct these deficiencies when the ship undergoes a major upgrade. The ship class then shifts from the Baseline Configuration to Baseline 1. Throughout both processes an area of concern for the SCIB is the validation of program cost estimates presented by the Program Office in NAVSEA. This is addressed in the following chapter.

V. SHIP COST ESTIMATION/VALIDATION PROCEDURES

A. INTRODUCTION

The Navy's cost estimation function has been established to:

1. Serve decision makers in allocating resources by providing them with reliable estimation of the resources required to develop, procure, and operate a new weapon system.

2. Assist in the overall planning, programming, and budgeting processes by providing reliable cost estimates for a new acquisition program.

The Navy currently uses a two-level evaluation process for program cost estimation. The Systems Commands are tasked with the preparation of cost estimates for a new weapon system and OPNAV is charged with the validation of these estimates. [Ref. 10]

Ship acquisition programs which are taken to the DAB/NPDM forums for Milestones I, II and III approval, must be supported by the cost estimate presented by the Program Manager as well as by an independent cost estimate (ICE). The Naval Center for Cost Analysis (NCA) is responsible for preparing the ICE for all OPNAV ship programs. [Ref. 11:p. 1] However, the Class "F" (ballpark) and Class "C" (budget quality) cost estimates presented to the SCIB working groups and full SCIB membership for review are prepared solely by the cost analysts in NAVSEA. The SCIB will often request that NCA conduct a "cost assessment" for a program under

review. However, this assessment is only a quick check of NAVSEA's cost estimate for reasonableness. It is not an independent estimate.

B. COST ANALYSIS GROUPS

On 1 October 1985, the OPNAV cost group (OP-917) merged with the former cost group from the Naval Material Command (NAVMAT) to form the Naval Center for Cost Analysis. NCA has the unique mission of developing the Navy's independent cost estimates for ACAT I, II and III programs in support of the decision-making process prior to major program milestones. The primary tasks of the NCA cost analysts are to review the program cost estimates of the systems commands (NAVSEA) and prepare their own independent estimate to assess the reasonableness of the program cost estimates. [Ref. 11:p. A-3] NCA has seven professional ship cost analysts.

NAVSEA ship cost analysis group is SEA-017. Its primary mission is to provide an unbiased program cost estimate to support the PPBS process and to ensure that the cost estimate used for budget development contains enough money for the program manager to execute the acquisition strategy. SEA-017 reviews the cost estimates developed by the program office, makes necessary adjustments, and validates the estimate as the official NAVSEA cost estimate. SEA-017 has approximately 50 professional ship cost analysts.

C. COST ESTIMATING METHODOLOGIES

The construction cost of a new ship is based on the ship work breakdown structure (SWBS), presented in Figure 14. Ship costs are built up from three-digit-level cost categories to the one-digit level categories that define the individual products to be produced and relate the elements of work to be accomplished to the final product (the ship). Combat Systems costs dominate all other costs that make up the ship acquisition cost. However, the ship acquisition cost is typically just 50 percent of the ship's life-cycle cost. The other 50 percent is operating and support costs. Figure 15 shows the typical acquisition cost of a surface combatant, Figure 16 shows the operating and support cost and Figure 17 shows the life-cycle cost of a surface combatant. [Ref. 12:p. 70]

There are three classic cost estimating techniques used to define these ship costs: parametric modeling, specific analogies, and engineering build-up. The NCA cost analysts use parametric modeling. This methodology is based on statistical cost estimating relationships (CERs). CERs are defined as

> ...an estimate which predicts cost by means of explanatory variables such as performance characteristics, physical characteristics, and characteristics relevant to the development process, as derived from expensive or logically related systems. They are mathematical equations which relate system costs to various explanatory variables derived through statistical regression techniques or historical cost data. [Ref. 13:p. 9]

Cost Group	Identification
100	Hull structure
200	Propulsion plant
300	Electric plant
400	Command and surveillance
500	Auxiliary systems
600	Outfit and furnishings
700	Armament
800	Integration/engineering
900	Ship assembly and support services

Figure 14. Ship Work Breakdown Structure (SWBS)

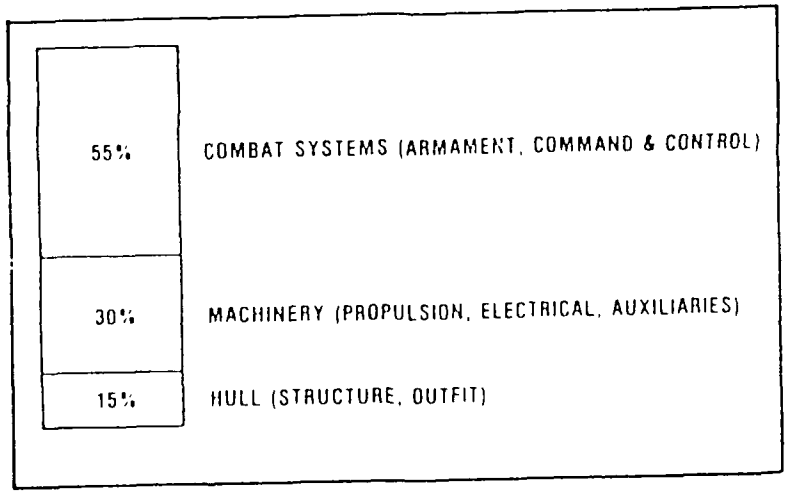


Figure 15. Acquisition Cost of a Surface Combatant

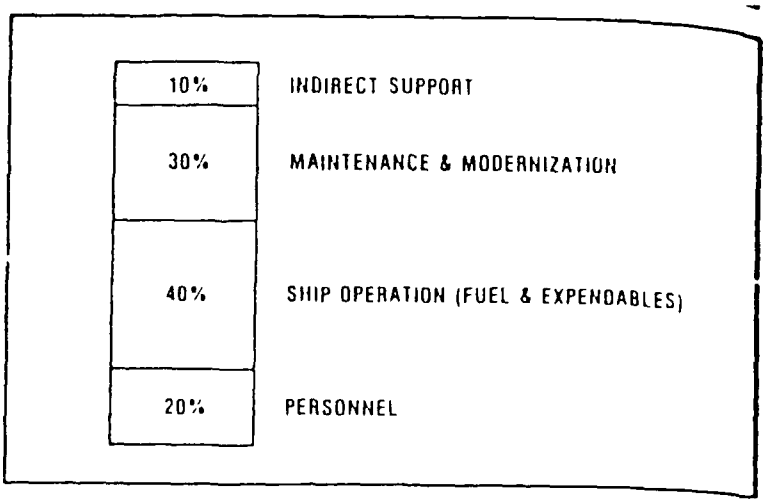


Figure 16. Operating and Support Cost of a Surface Combatant

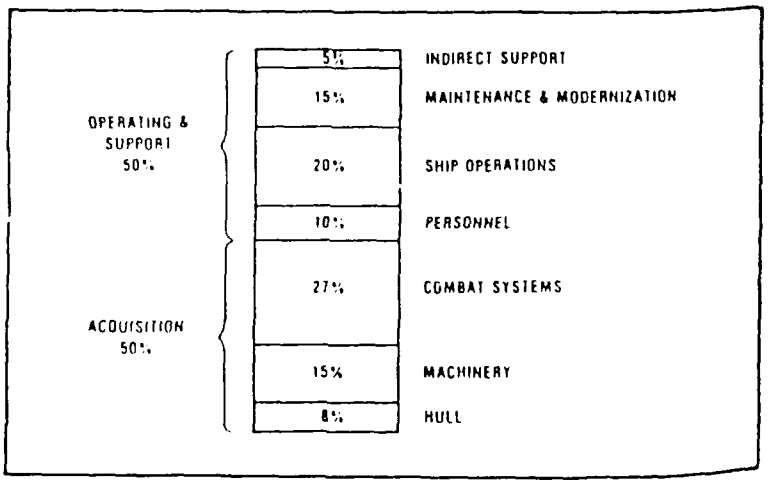


Figure 17. Life-Cycle Cost of a Surface Combatant

For naval ships, these performance and physical characteristics such as displacement, length, speed, manpower, propulsion, and weapon systems are documented in the Top Level Requirements (TLR). Derivation of CERs requires valid historical cost data by WBS in constant dollars.

The following equation is an example of a CER developed to relate the end cost (basic contract cost plus GFE) of a new escort ship to its performance characteristics. The CER is part of ESCOMO, a statistically derived model produced at the Center for Naval Analysis. [Ref. 13:p. 48]

$$\text{END COST (\$)} = 0.37615e^{0.087994\,MAXSP}\ CRWF^{0.57554} \times SONAR^{0.090806}\ e^{0.0025353\,ORD} \times SQYD^{-0.10001}$$

where:

MAXSP = Max speed in knots,

CRWF = Crew factor (quotient of full load displacement by crew accommodations),

SONAR = Sonar index,

ORD = Ordnance (guns and missiles) index,

SQYD = Building sequence by shipyard and class.

Because parametric modeling is based on the premise that the cost of a weapon system is related in quantifiable terms to its characteristics, it is particularly useful for cost estimates in the early stages of the acquisition process for a ship where requirements are being refined and characteris-

tics are being developed. These cost estimates can be used to:

1. Identify possible cost/performance tradeoffs during the feasibility study and preliminary design phases for a new ship.
2. Provide a base for cost/effectiveness review of performance specifications.
3. Provide information useful in ranking of competing options at the end of the preliminary design phase.
4. Suggest the need for identifying and considering new options. [Ref. 13:p. 13]

The cost analysts in the program office at NAVSEA also use CERs. However, they are "relatively simple measures of the cost to perform the tasks involved in shipbuilding, e.g., direct labor hours per ton, and are generally not derived with rigorous statistical techniques." [Ref. 11:p. 6] NAVSEA analysts primarily use Industrial Engineering (IE) techniques such as analogies and engineering cost build-up for specific ship portions, such as power-plant and auxiliary equipment that already exist in similar form on other ships. NAVSEA emphasizes its knowledge of industry costs and capacity as well as shipbuilding cost history. However, these techniques involve detailed studies of the operations and materials required to build a new ship. And they frequently require several thousand hours to produce with voluminous supporting documentation. Any changes in the ship's characteristics would require intensive changes in the cost estimates. Unexpected design changes often

bring about unexpected increases in the ship's costs. [Ref. 12:p. 13]

D. COST DATA COLLECTION

Historical cost data form the foundation for both Industrial Engineering and parametric modeling cost estimating methodologies. There are three major sources of cost data for the analysts. The first source is the contractor cost data report (CCDR). CCDR reporting is required for all ACAT I programs and other selected programs. This information provides the cost analysis community with the detailed historical costs experienced on acquisition programs to facilitate estimating future costs of emerging acquisitions. However, historical CCDR data are primarily for the use of the cost analysts and of little value to the program office. Therefore, some Program Managers have failed to require such data collection as a contract line item and the cost community has been left with an incomplete historical base for use in projecting the costs of future systems.

The second major source of cost information is the cost performance report (CPR) and its equivalent for small programs, the cost/schedule status report (CSSR). These reports are used as management tools on programs whose contract requires compliance with DOD cost/schedule control system criteria. NAVSEA Program Managers use these standard

reports to track the progress of construction of individual ships.

The final source of cost data is obtained directly by the cost analysts from contractor personnel. This informal process has emerged because the Navy's standard cost-report systems are often inadequate for the needs of the cost analysts. [Ref. 11:pp. 14-15]

Because of the shortage in the number of cost analysts, the lack of time to gather information and the absence of a Navy-wide automated data system, the Naval Center for Cost Analysis is particularly dependent on the CDDR data that can only be obtained by the Program Manager. And as previously stated, these reporting requirements are not consistently enforced.

E. NAVAL CENTER FOR COST ANALYSIS PROCEDURES

The Naval Center for Cost Analysis Charter (draft) provides the documentation requirements for the development of an ICE by NCA analysts. Documentation by the cost analyst must be "sufficiently detailed" to provide:

1. A clear statement of the basic method and approach used to derive the cost estimate.
2. For an understanding and evaluation of the estimate by other cost analysts.
3. The reviewer the ability to reconstruct the cost analysis and estimate.
4. A track record for comparison with prior and subsequent cost estimates.

The precise format and content of an ICE will vary depending upon the type and purpose of the cost estimate. There are, however, 11 key elements that must be addressed in every cost estimate. [Ref. 15] These elements are:

1. Date of Estimate--This is the date on which the analysis/estimate, or change in the estimate, is completed by the originator.

2. Category of Estimate--This identifies the classification of the cost and the rationale for the assigned class (i.e., Class "C" or "F").

3. Preparing Organization--This is to include the NCA department and if any part of the estimate was provided by a support contractor, this must be noted and the source must be identified.

4. Purpose of the Estimate--The specific purposes of the estimate must be identified (design tradeoff, milestone decision, budget submission or program policy development). Estimates should also be linked to earlier or related estimates by specifically identifying those estimates and their source documents.

5. Description of System--This must include a summary of the physical and performance characteristics of the ship that are pertinent to the estimate. Significant changes in the program or characteristics since the last estimate was made should be highlighted and the Ship Work Breakdown Structure (SWBS) should be shown.

6. Ground Rules, Assumptions, Constraints--This is to include those that are both directed and self-imposed. Ground rules could include time frame of acquisition, year and type of costs, and source of economic factors (such as inflation). Implicit and explicit assumptions could include acquisition schedule, cost factors, procurement and production methods, cost model parameters, degree of competition, nature of risks, and resource availability (i.e., Government Furnished Equipment (GFE)). Constraint could include limitations on time and resources available for the analysis, restricted access to data sources, or the unavailability of appropriate models for the analysis.

7. Data Sources--This describes and references specific sources of all data (program, technical, cost) used in

making the estimate. Modifications or adjustments to data and the exclusion of data must be addressed with supporting justification. Major gaps in the data must be identified along with a description of actions taken to fill them. The year of cost data used must be provided.

8. Estimating Methodology--Describes the methods used to estimate every cost/SWBS element. If established cost estimating models were used, identify the model, and present a summary description and source. If new estimating relationships were developed, describe their derivation. Cost/quantity relationships and time-phasing methods used must be described.

9. Estimates--Provides estimates to the lowest level developed. Gives time-phasing and budget/ appropriation categories of all estimates. Describes the success or failure of the test for reasonableness for the Program Managers estimates.

10. Design to Cost--Design to Cost (DTC) requirements for the systems must be provided along with the DTC goals related to the estimate. If estimate appears inconsistent with the DTC goals, discuss implications of the differences.

11. Uncertainty and Risk--Describes the uncertainty analysis conducted for the estimate. Provides qualitative or quantitative uncertainty measures for the estimate. A measure of overall confidence or uncertainty in the estimate must be provided.

F. SUMMARY

The Navy currently uses a two step process for ship costing. NAVSEA cost analysts develop a ship cost estimate based on Industrial Engineering techniques. The Naval Center for Cost Analysis is then tasked to develop an independent cost estimate. This is to be an assessment of the cost estimate provided by the Program Manager in NAVSEA. The NCA cost analysts use parametric models for cost estimating, developed in-house or by private firms under

contract. These models, however, are only as good as the historical data base maintained for cost estimating and the assumed parameters and their relationship to cost. The format of an ICE is dependent upon the particular program under review. However, there are 11 key elements that the cost analyst must address. Finally, an ICE is only prepared for each Milestone decision at the DAB/NPDM forums.

Due to time limitation and obvious manpower shortages at NCA, the SCIB currently does not have access to independent cost estimation data when refining operational requirements and developing ship characteristics in the early stages of the ship acquisition process. NCA cost analysts do provide the SCIB with cost assessments. However, these are just quick reviews of NAVSEA cost estimates and do not provide decision makers the advantages of an independent estimate based on a different estimating methodology.

VI. SUMMARY, EMERGING PROBLEMS AND RECOMMENDATIONS

A. SUMMARY

The Navy's ship design process has evolved over the past 50 years. This research has focused on the most recent and significant improvement in the design process. The CNO established the Ship Characteristics and Improvement Board in 1982 to improve the communication between those responsible for planning the Navy's surface force structure in OPNAV and the ship design engineers at NAVSEA and formalize the process for characteristic development and improvement for naval ships.

The SCIB's primary role as a sub-panel of the CNO Executive Board is to assist the CNO in all matters that pertain to ship acquisition and improvement by coordinating the formulation of Navy shipbuilding and conversion programs. The SCIB is chaired by the Assistant Chief of Naval operations for Surface Warfare (OP-03). Its membership includes the heads of all the major offices in OPNAV, the Commanders of NAVSEA and SPAWAR, the Commandant of the Marine Corps, and representatives from the Office of the Secretary of the Navy. The key coordinating element in the SCIB process is the working groups. The working group is the forum in which the ship operators and design engineers resolve issues and ultimately articulate ship

requirements and characteristics. Finally, the SCIB is supported by a permanent staff (OP-03C).

The SCIB administers a formal process of milestone documentation to perform its functions. The development of the characteristics for a new ship begins with the Tentative Operational Requirement. The TOR provides the NAVSEA design engineers a general statement of the perceived requirements and desired capabilities for the new ship. The Top Level Requirements is the Navy's final statement of the approved characteristics and design requirements for the new ship. After fleet introduction, OPNAV controls changes to ship characteristics through the development of a Warfighting Improvement Plan for each ship class. The WIP identifies warfighting deficiencies and provides the alterations required to correct these deficiencies when the ship undergoes a major upgrade.

The key to the success of any acquisition program is the accurate determination of the resources required to procure and operate the system. The Navy uses a two step process for the determination of ship costs. The Program Manager at NAVSEA provides the official cost estimate for a ship program. This estimate is developed by NAVSEA cost analysts using Industrial Engineering techniques for cost estimating. The Naval Center for Cost Analysis is responsible for the validation of this cost by developing an independent cost estimate. The NCA cost analysts use parametric models to

develop the ICE. However, the ICE is only developed to support milestone decisions at the DAB/NPDM forums. The SCIB does not have access to an independent estimate during the early stages of characteristics development.

Finally, ship program cost estimates include both life cycle and acquisition costs. However, acquisition cost has a greater influence on the SCIB decision making process. This is primarily due to the fact that a ship's acquisition cost is more easily measured and has an immediate impact on Navy programming. Also, program cost constraints are usually imposed as the maximum acquisition cost per ship.

B. EMERGING PROBLEMS

Since the SCIB was established in 1982 several problems have emerged that challenge the continued success of the ship characteristics development process.

The first set of problems concerns the emergence of certain trends within the SCIB working groups. The working groups were originally designed for the CAPT/CDR and GM 14/15 levels. However, the grades of the participants have been slowly decreasing. Along with this trend, the level of knowledge and experience brought to the working group discussions has also dropped. Another negative trend has been the lack of participation in the working group process by many of the representatives of the SCIB membership. Most of the discussions are dominated by the OPNAV program sponsor and NAVSEA program office representatives. To be

truly effective, the working group requires active participation by representatives from all the OPNAV offices.

Another internal problem has to do with the emergence of the "paper SCIB." For many non-controversial and smaller (in terms of political interest as well as money) programs, a full SCIB meeting is not convened for program decisions. The SCIB principals are briefed by the working group members and vote in absentia for the recommended option. This "paper SCIB" has evolved more out of convenience than efficiency. It has been noted that one of the "fringe benefits" of the SCIB process is the improved communication at the most senior levels of the Navy. The SCIB has provided a useful vehicle for getting top level attention on some non-ship specific issues. This fringe benefit is lost every time a program decision is made by a "paper SCIB."

The final internal problem deals with the Warfare Improvement Program. Due to the fiscal constraints imposed on the OPNAV program sponsors, a WIP developed for a ship class has yet to be fully funded and implemented. Only corrections to the most critical warfare deficiencies are programmed and installed. A considerable amount of time, money and effort goes into the WIP development. However, these resources are essentially wasted if the recommendations are not funded. Consequently, WIP development is now a low priority for the SCIB.

An external problem that has an effect on the SCIB process is the limited support provided by the Naval Center for Cost Analysis. Due to time limitations and resource restrictions, NCA cost analysts can only provide the SCIB a quick cost assessment to assist in program decision making. However, an independent cost estimate would complement the NAVSEA cost estimate and compensate for the internal weaknesses in the NAVSEA estimating methodologies and provide the SCIB more information during early tradeoff analysis.

C. RECOMMENDATIONS

The problems internal to the SCIB process can be effectively managed by the SCIB leadership. When a SCIB working group is formed for a new program, the individual SCIB principals must ensure that his representative is of the appropriate grade and has the experience and expertise necessary to articulate and support the policies of his organization. The importance of active participation must be stressed by both the SCIB leadership and the chairmen of the individual working groups. Finally, downgrading the priority of WIP development because of fiscal constraints is not an appropriate response. Instead of waiting for a program sponsor to initiate WIP development for a particular ship class, the SCIB should prioritize ship classes and warfare mission areas. Once the funds become available for

baseline upgrades, WIPs should be developed according to this priority list.

The small number of ship cost analysts at the Naval Center for Cost Analysis greatly restricts its ability to support the SCIB process. However, two changes can be made that would greatly enhance the effectiveness of the NCA cost group. Historically, management has paid little attention to the problems of cost analysts and their need for supporting cost data bases. Therefore, cost data collection should be made a contractual requirement, removed from the discretion of the program manager or the private contractor. Secondly, the development of an automated data base for ship costs should be actively pursued by both the Commander of NAVSEA and the Director of NCA. Automating data bases is quite difficult, but it is feasible (as demonstrated by NAVAIR) and the effort would be well worth it.

The CNO has not established a set of standards to evaluate the SCIB's performance. However, certain measures do indicate its success. The SCIB has formalized the ship characteristics and improvement process and established clearly defined lines of communications between OPNAV and NAVSEA. Ship programs are now required to pass through a multi-level revision process and can not advance without the proper documentation required by the acquisition process. And the Navy is better able to articulate its shipbuilding and conversion program to Congress. The Secretary of the

Navy, John Lehman, was so pleased with the SCIB that he ordered the establishment of an Air Characteristics and Improvement Board.

As previously stated, the ship design process is evolutionary. The next challenge for the SCIB and the Navy in general will be to move forward from a decision making process based on an individual ship structure to one based on the battle force structure.

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